Ocean Cavities Below Ice Shelves

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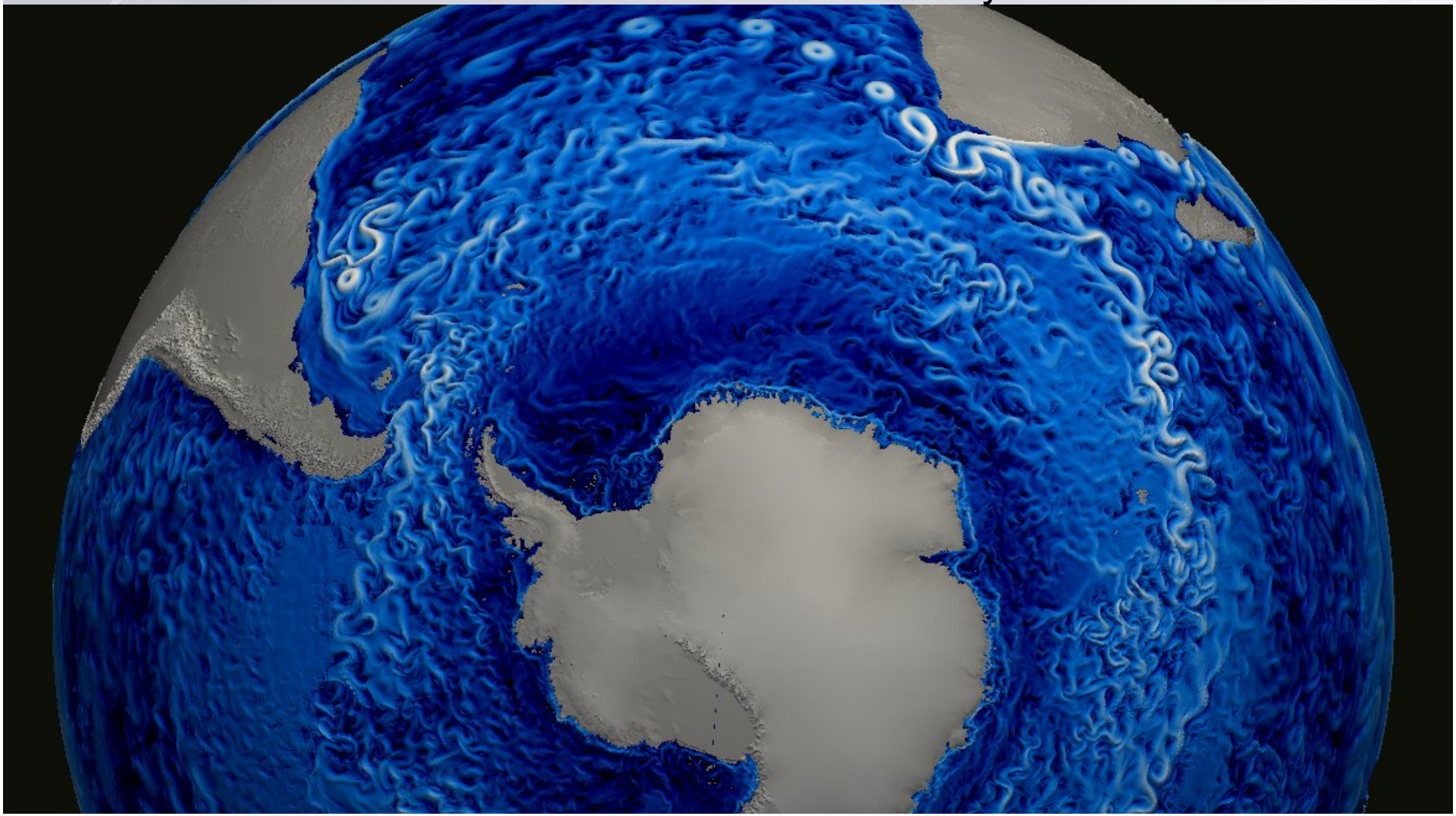
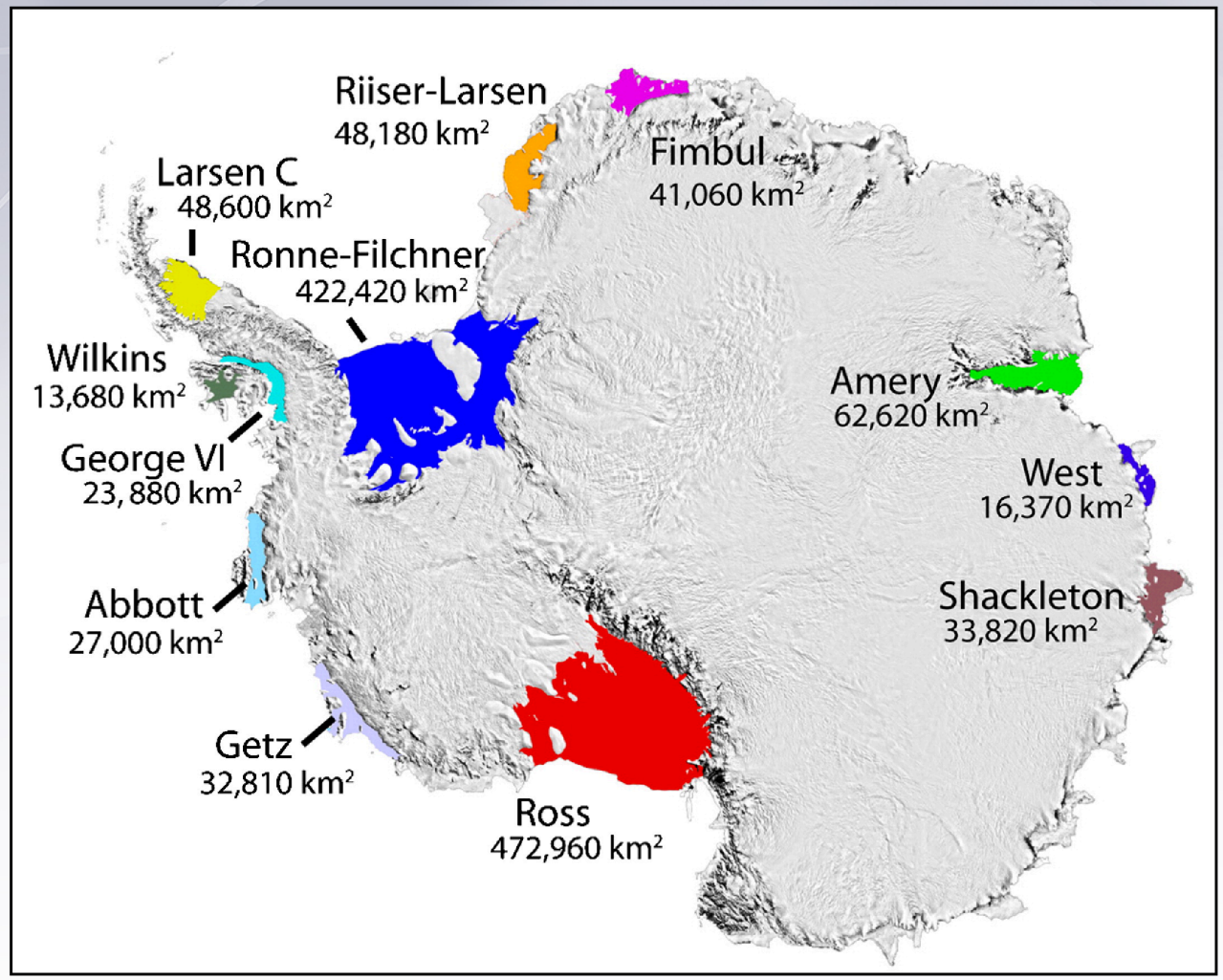
Matthew Hoffman, Adrian Turner, Jon Wolfe, Stephen Price

Los Alamos National Laboratory

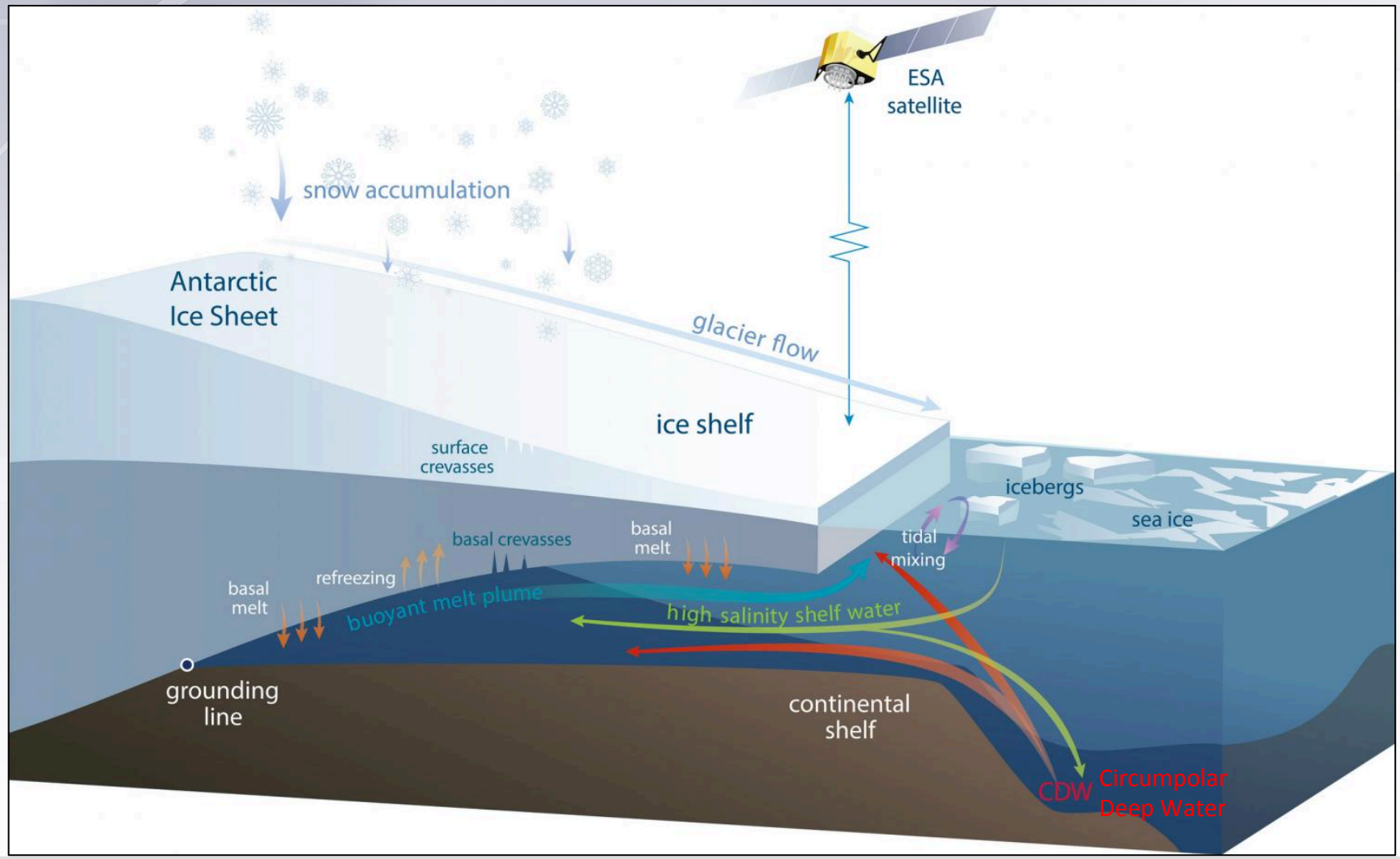


Ocean Cavities

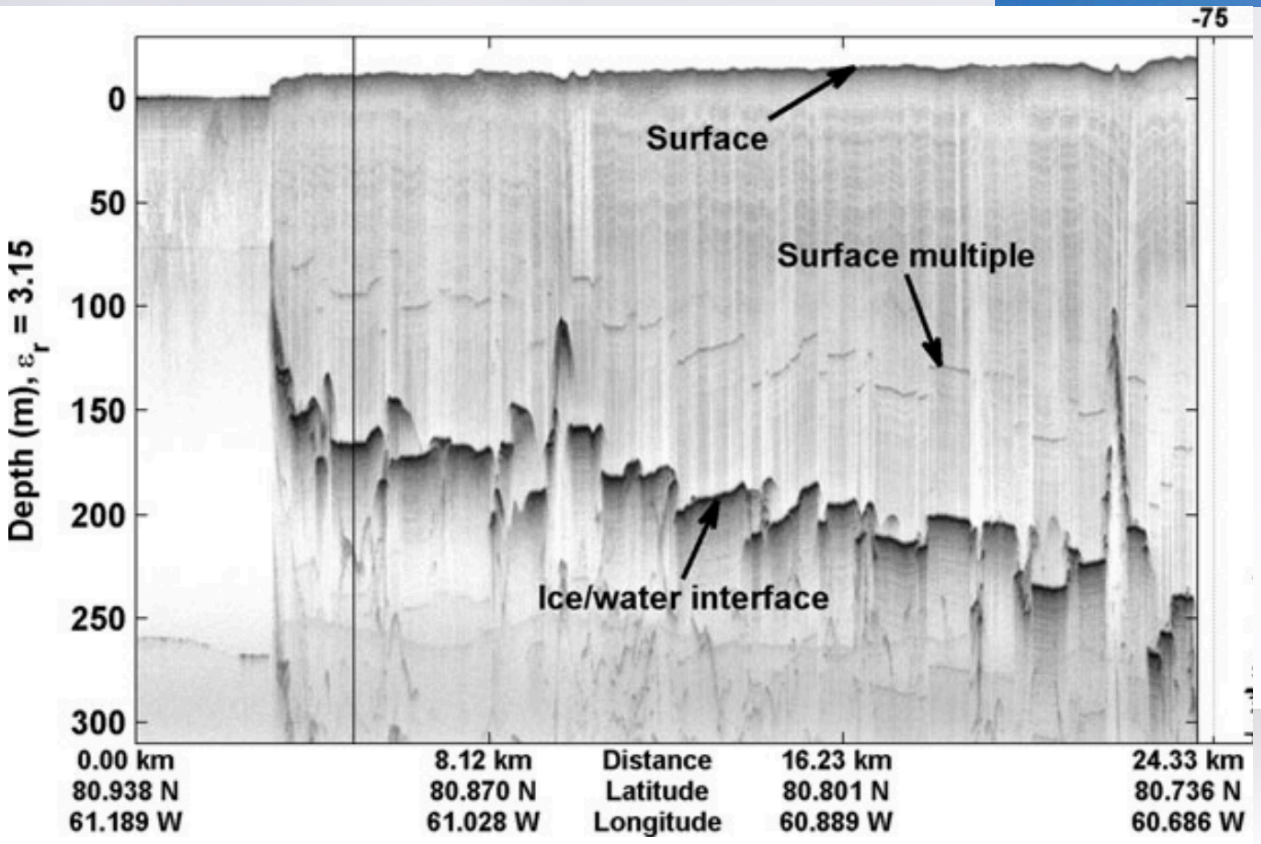


https://nsidc.org/cryosphere/quickfacts/iceshelves.html

Ocean Cavities



Ground penetrating RADAR



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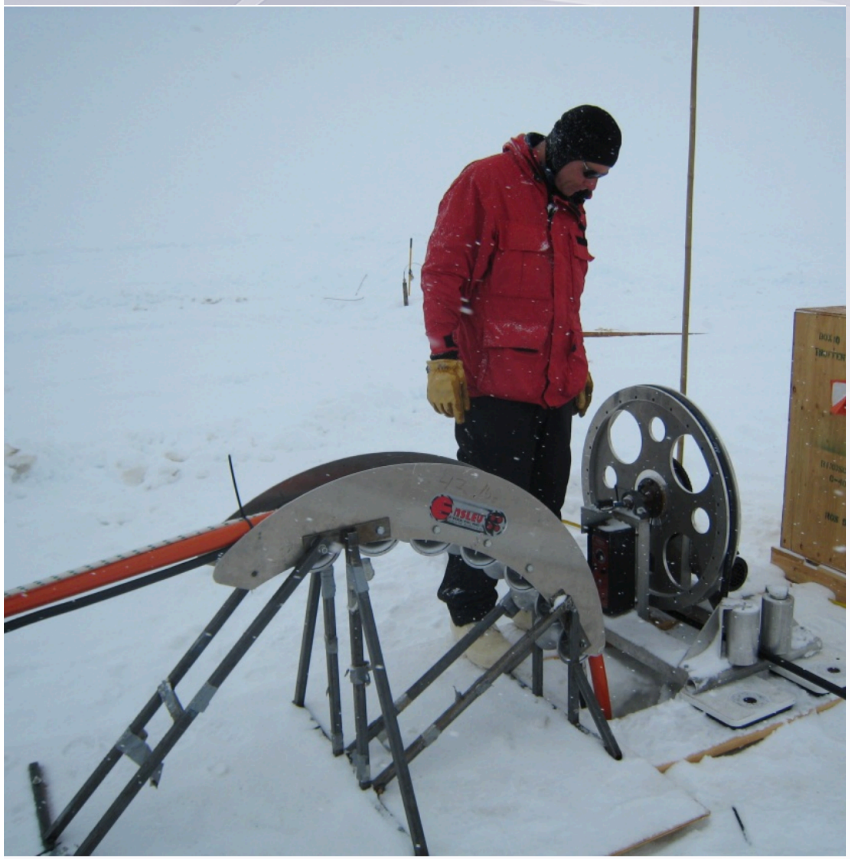
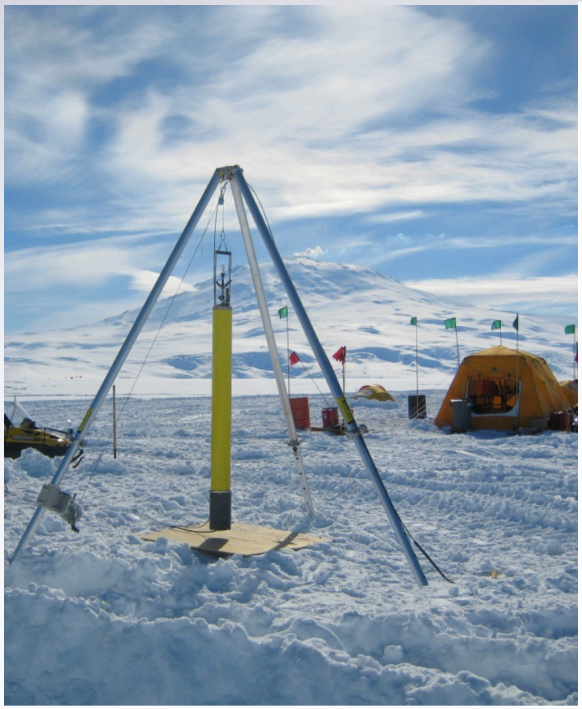
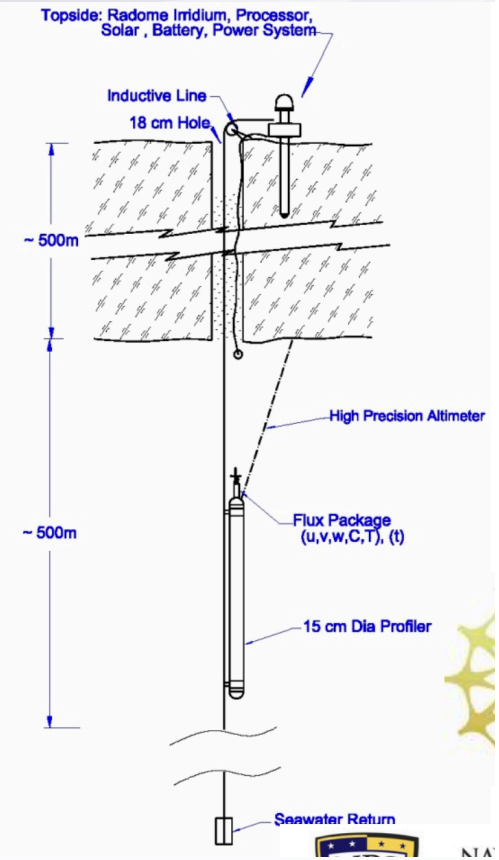
Observations of Ocean Cavities

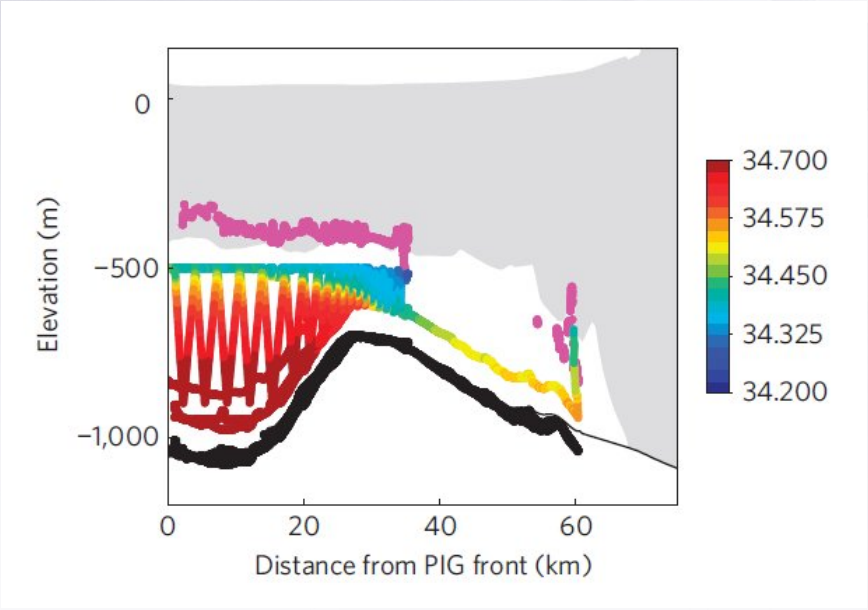






Source:http://www.nasa.gov/pdf/601839main_Tim.pdf
Tim Stanton and Bill Shaw, Naval Postgraduate School

Autonomous submersibles



Observations of salinity below the Pine Island Glacier (Jenkins et al. 2010, Nature Geosciences)

Importance of Ocean Cavities

The constraints on the oceanic delivery of heat to Antarctic ice shelves and its impact on melt rates remains critically under-studied.

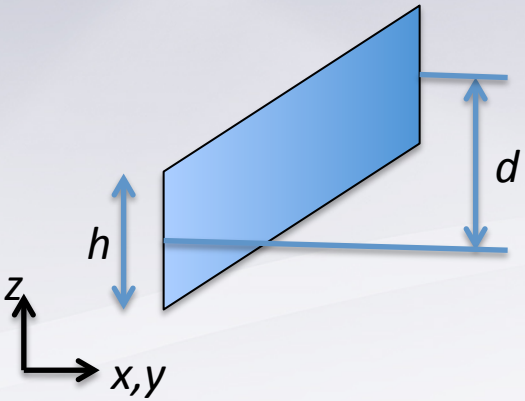
Our inability to constrain the rate of retreat of Antarctic glaciers and how the Antarctic Ice Sheet will behave in a warming climate remains the single most significant reason for the large uncertainty in sea level projections over the 21st century.

Ocean-Ice interactions in Antarctica stand as one of the grand challenges of climate science today

Study Report "The Sleeping Giant: Measuring Ocean-Ice Interactions in the Antarctic"
Sponsored by the Keck Institute for Space Studies, December 2015

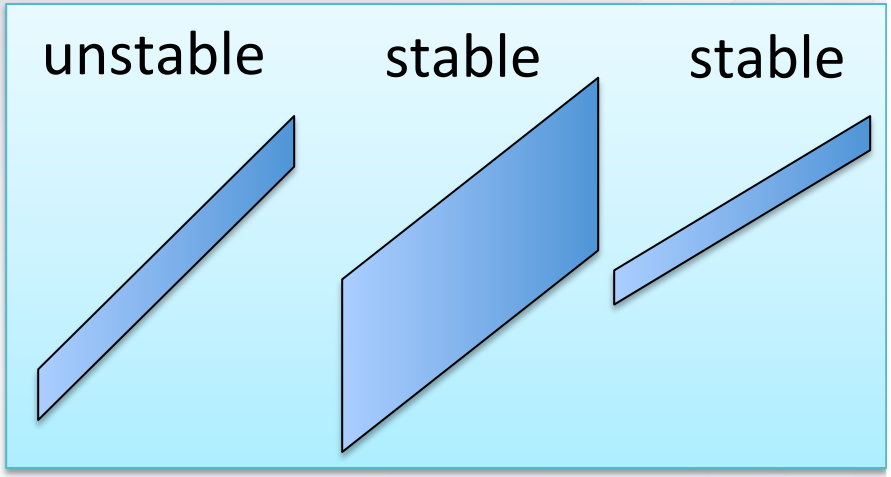
MPAS-Ocean Vertical Grid

- Versatile Arbitrary Lagrangian-Eulerian (ALE) Vertical Grid and new pressure gradient formulation allows tilted cells
- Stability criterion for severely tilted cells:

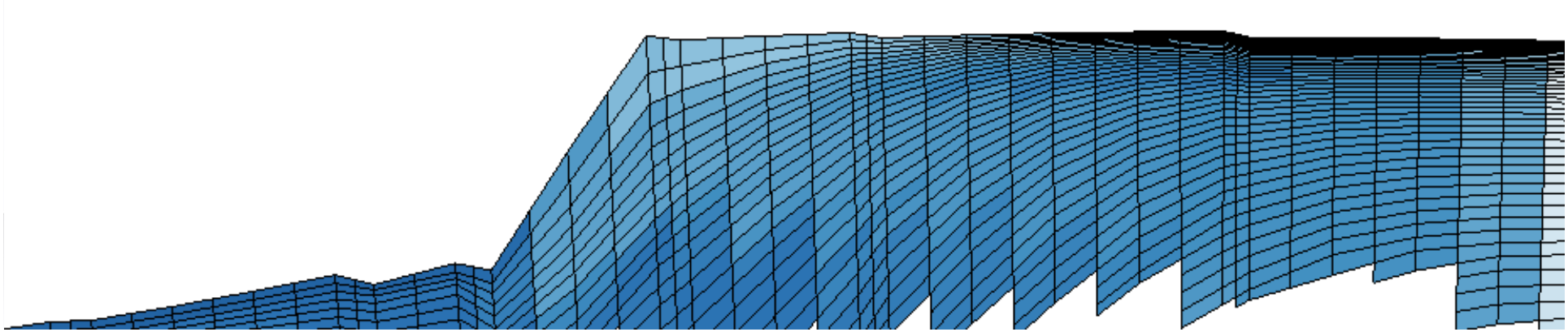


Haney number

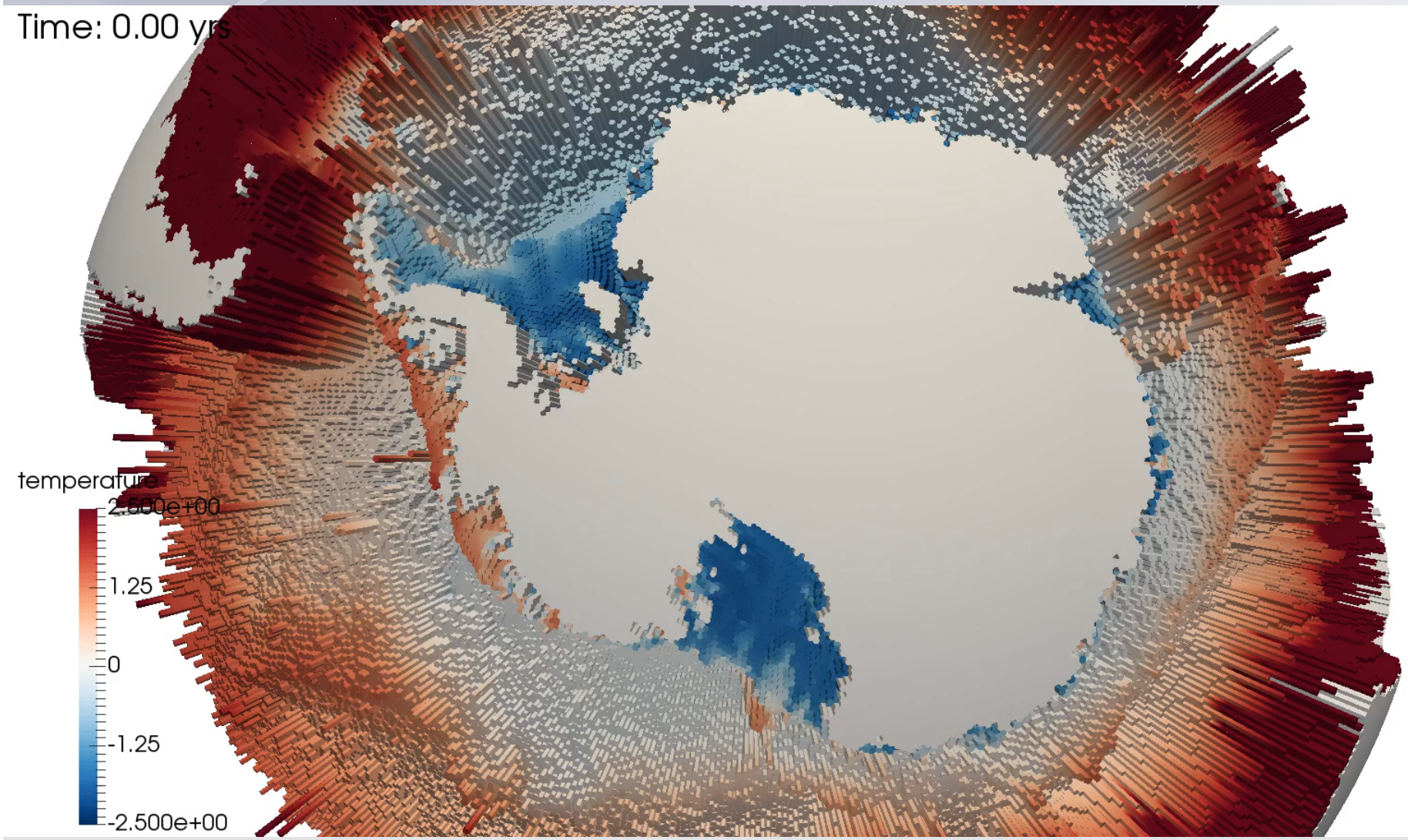
$d/h < 5$



- New ocean grid initialization method enforces stability

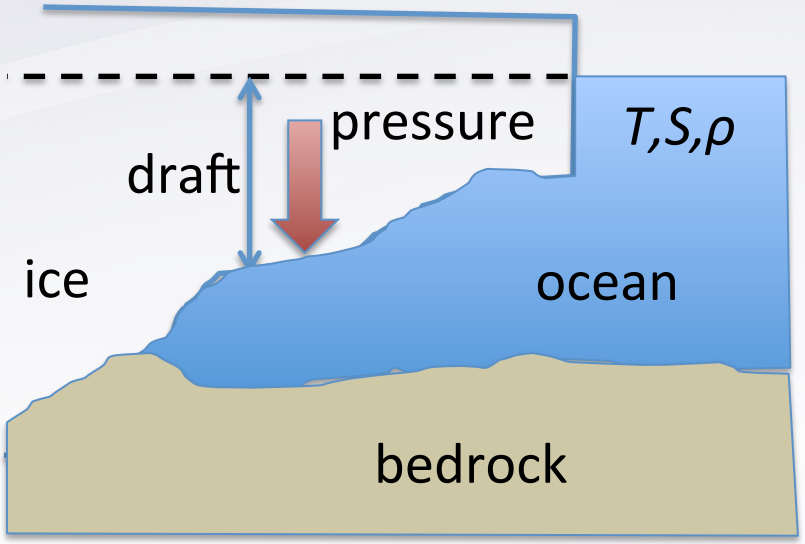


ACME B Case (active ocean, sea ice, atmosphere)
EC 60-30 km ocean with static ice shelves



Ocean Model: Ice Draft/Ice Pressure

- On start-up, draft and pressure must be in static balance.
- Ice draft is obtained is from observations
- Pressure depends on density of *displaced* water
- New, iterative initialization solves for balanced pressure

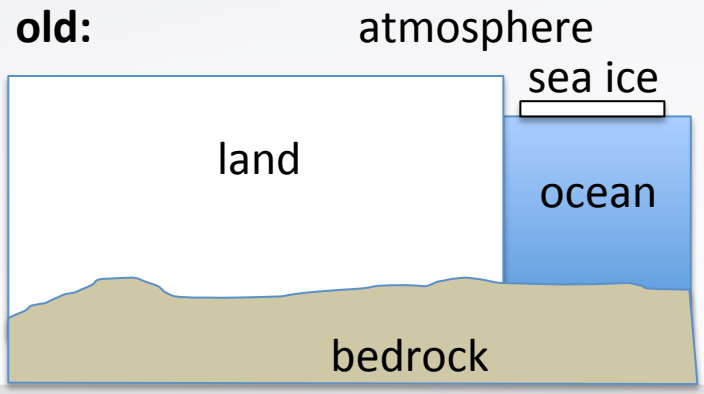


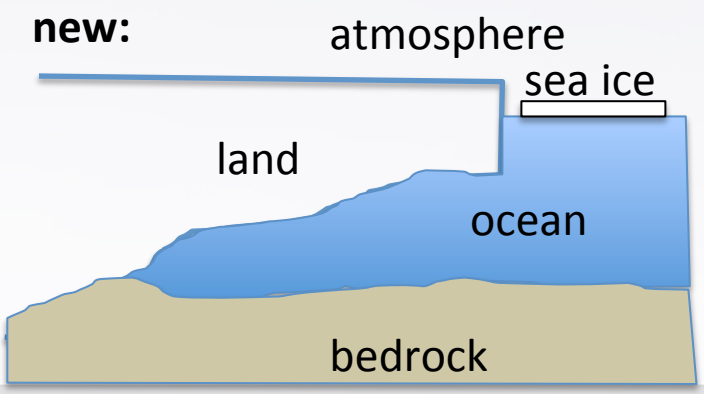
Hydrostatic balance

$$p = \int \rho(z) g dz$$

Changes for Static Cavities: Coupling

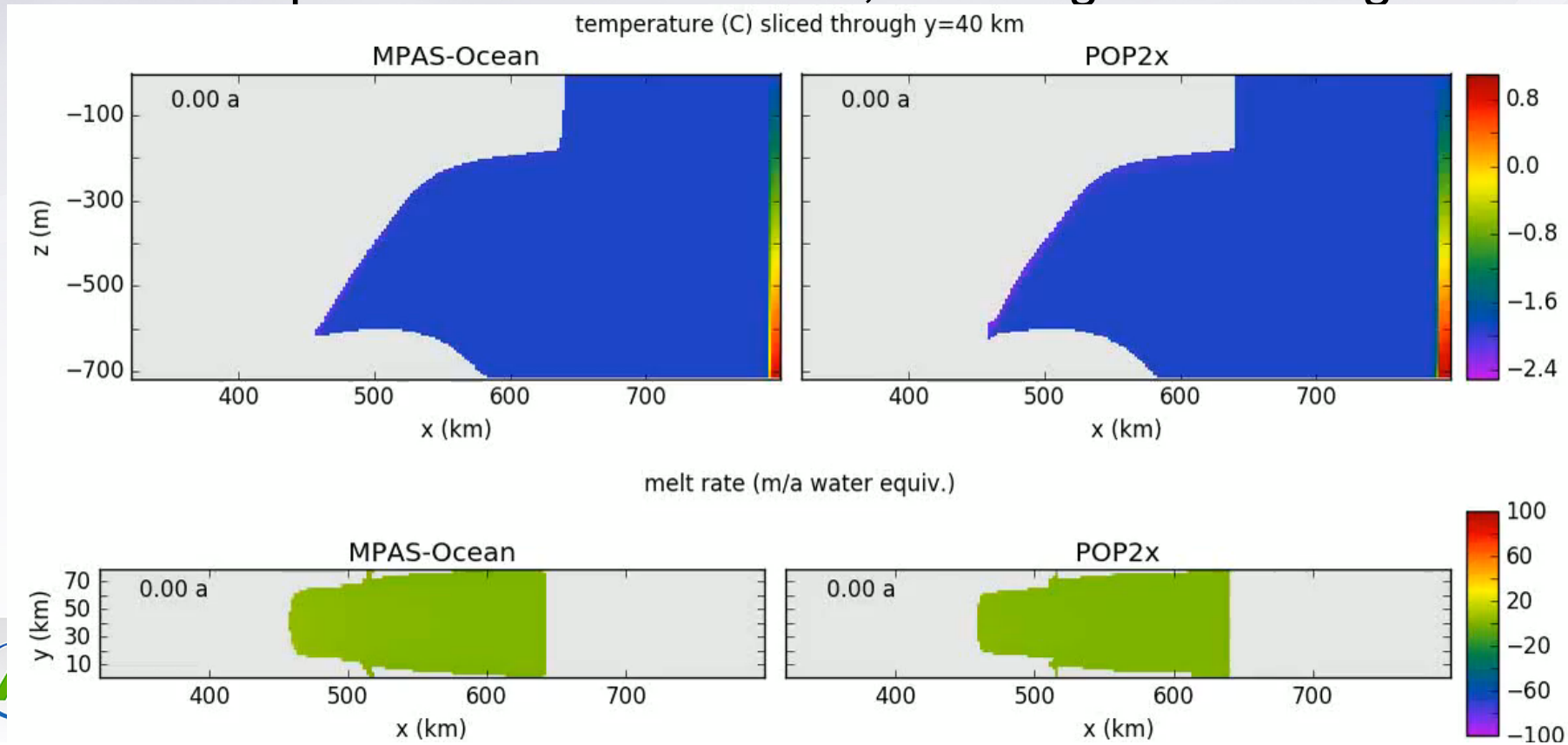
- Before: globe was partitioned into land *or* ocean
- Now: ocean may underlie land model:
  1. Atmosphere sees same land/ocean partition as previously
  2. Sea ice fluxes below open ocean, land ice fluxes below ice shelves
  3. Land runoff must be delivered to edge of land (not ocean)
- Changes were to mapping files, not coupler code.





Idealized Testing

- Second Ice Shelf-Ocean Model Inter-comparison Project (ISOMIP+): steep channel with warm water at seafloor
- Induces strong melt rates (100m/yr)
- Flows up underside of ice shelf, inducing overturning



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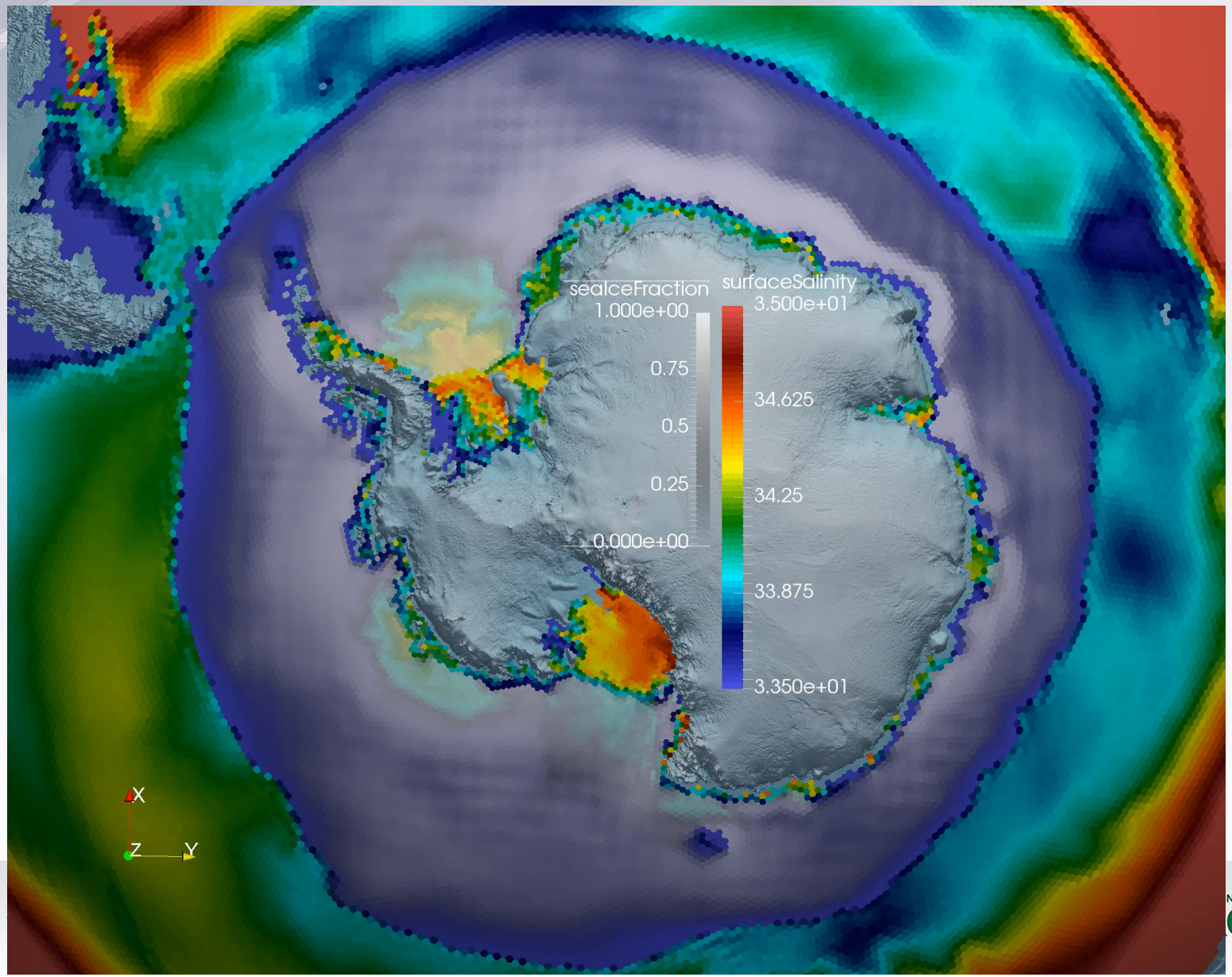

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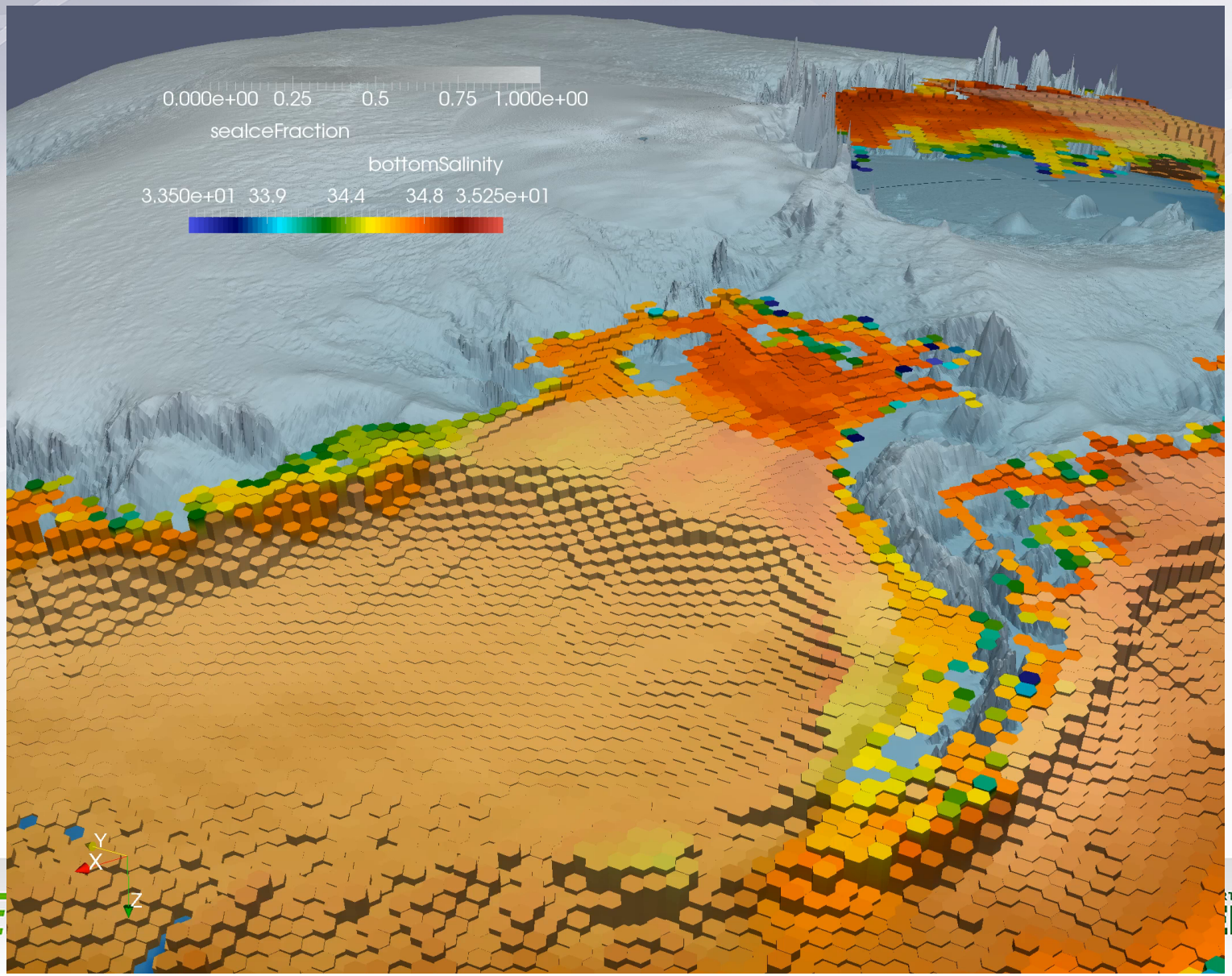
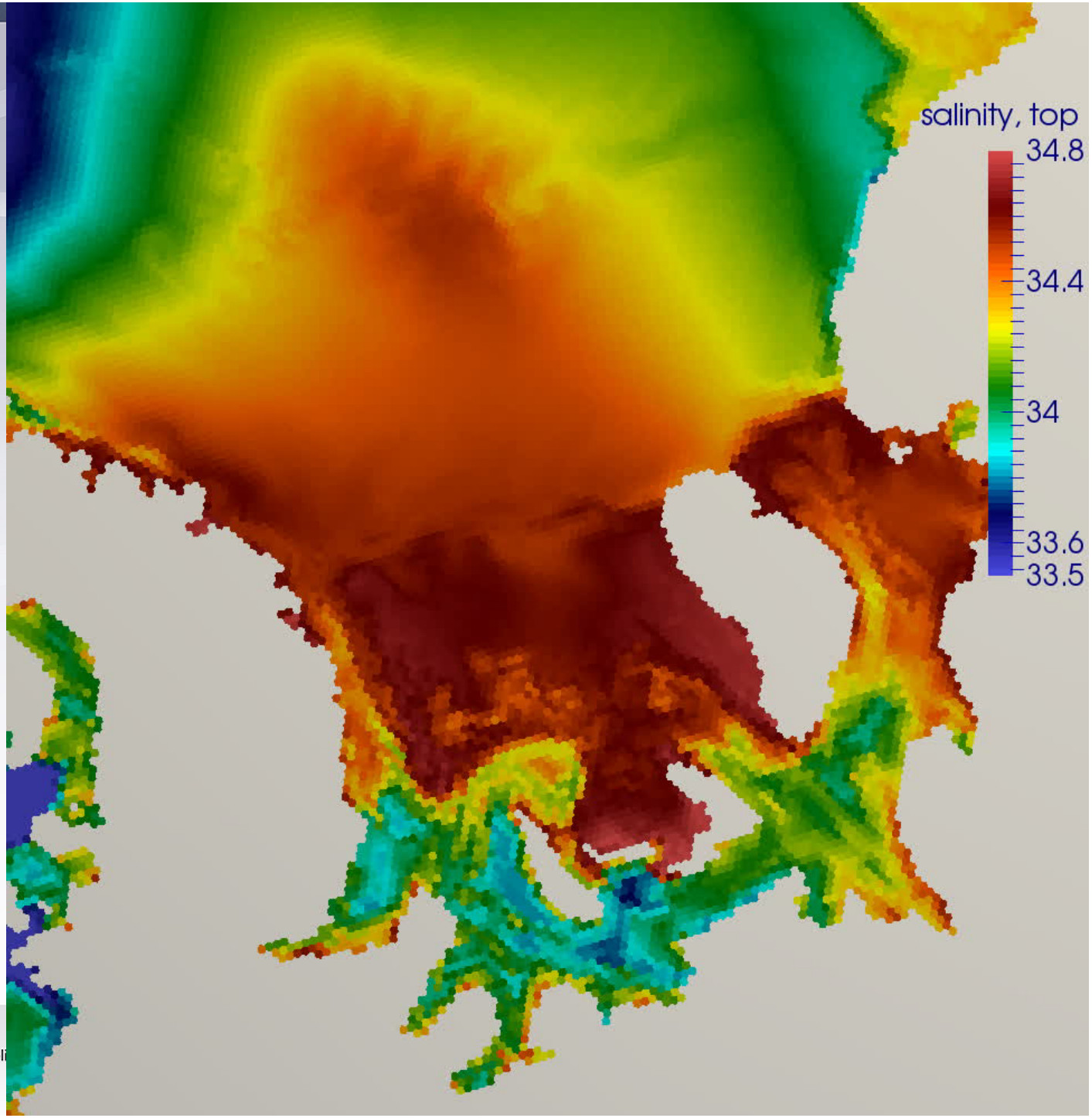


RRS 30-10 km
MPAS-Ocean
stand alone



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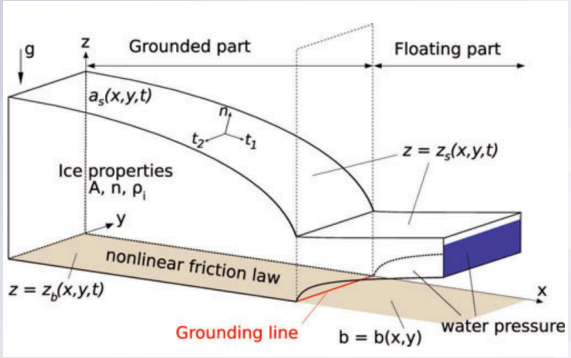
for Energy

Simulating Marine Ice Sheet Dynamics in MPAS Land Ice

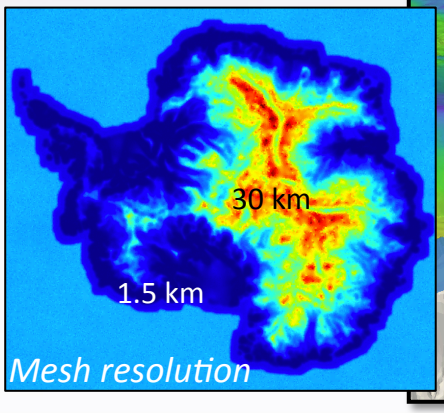
Grounding line dynamics:

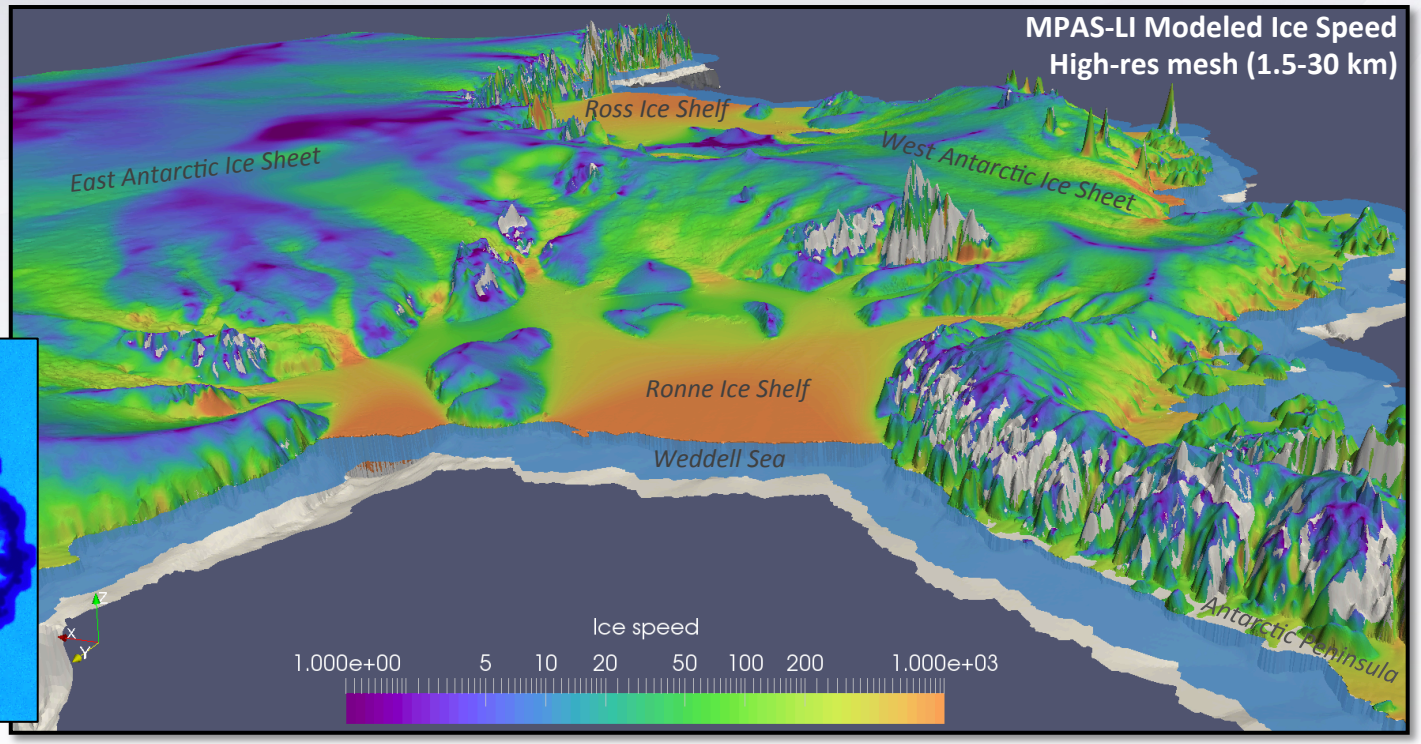
- Processes there have a first-order control on ice sheet stability and associated sea level changes.
- Challenging to model accurately in ice sheet models.
- MPAS-LI recently passed the MISMIP3D benchmark test for marine ice sheets, indicating readiness for Antarctica simulations. *(poster: Matt Hoffman)*



Variable resolution meshes

- Guided by MISMIP3D results
- Low, Mid, and High res AIS meshes complete
- In testing phase





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What's next?

- Run ACME with static ocean cavities
  - B Case: active ocean, sea ice, atmosphere, land
  - G Case: CORE-II forcing, active ocean, sea ice
- Evaluate ocean cavities, compare to available observations
- How do sub-shelf currents change in a warming climate?

Future Work:

- Run ACME with active land ice model
- Dynamic ice shelf extent would require:
  - Wetting/drying of ocean cells (V2) for grounding line motion
  - Coupling masks that change dynamically
  - Improved calving model
- Investigate ice shelf melting and instabilities, SLR